

1970

Fatty Acid Composition of Batter Coated Chicken Parts.

James Lee Heath III

Louisiana State University and Agricultural & Mechanical College

Follow this and additional works at: https://digitalcommons.lsu.edu/gradschool_disstheses

Recommended Citation

Heath, James Lee III, "Fatty Acid Composition of Batter Coated Chicken Parts." (1970). *LSU Historical Dissertations and Theses*. 1782.
https://digitalcommons.lsu.edu/gradschool_disstheses/1782

This Dissertation is brought to you for free and open access by the Graduate School at LSU Digital Commons. It has been accepted for inclusion in LSU Historical Dissertations and Theses by an authorized administrator of LSU Digital Commons. For more information, please contact gradetd@lsu.edu.

71-3414

HEATH III, James Lee, 1939-
FATTY ACID COMPOSITION OF BATTER COATED
CHICKEN PARTS.

The Louisiana State University and Agricultural
and Mechanical College, Ph.D., 1970
Agriculture, general

University Microfilms, Inc., Ann Arbor, Michigan

FATTY ACID COMPOSITION OF BATTER COATED
CHICKEN PARTS

A Dissertation

Submitted to the Graduate Faculty of the
Louisiana State University and
Agricultural and Mechanical College
in partial fulfillment of the
requirements for the degree of
Doctor of Philosophy

in

The Department of Poultry Science

by

James Lee Heath III

B.S., Louisiana State University, 1963

M.S., Louisiana State University, 1968

May, 1970

ACKNOWLEDGMENTS

This study would not have been possible without the assistance of many persons. I would like to take this opportunity to express my gratitude for their help and support.

Special appreciation is extended to Dr. R. A. Teekell for his guidance, advice, and encouragement throughout the study.

A special expression of gratitude is extended to Dr. A. B. Watts, Head, Poultry Science Department, for his encouragement, advice, and for making graduate study a possibility.

Sincere appreciation is extended to Dr. W. A. Johnson for his assistance in the analysis of the data from this experiment.

Special thanks are expressed to all members of the faculty, staff and graduate students for the help they gave.

To my wife, Mary, I wish to express heartfelt thanks for her patience, understanding, encouragement, and all the things which words cannot express without which this work could not have been accomplished.

TABLE OF CONTENTS

	Page
I. ACKNOWLEDGEMENTS	ii
II. LIST OF TABLES	iv
III. ABSTRACT	vi
IV. INTRODUCTION	1
V. REVIEW OF LITERATURE	3
VI. EXPERIMENTAL PROCEDURE	15
VII. RESULTS AND DISCUSSION	22
VIII. SUMMARY	77
IX. CONCLUSIONS	79
X. REFERENCES	81
XI. AUTOBIOGRAPHY	85

LIST OF TABLES

TABLE	Page
I. Analysis of variance of factors influencing fatty acid composition of batter used in deep fat frying of chicken	23
II. The distribution of fatty acids in various cooking oils before and after use	27
III. The fatty acid content of batter samples after cooking in various oils	31
IV. The fatty acid content of batter samples after cooking for various time periods . .	35
V. The fatty acid content of the various batters after cooking	38
VI. The fatty acid content of batter as influenced by both batter recipe and time .	45
VII. The fatty acid content of batter as influenced by both oil and batter recipe .	48
VIII. The fatty acid content of batter as influenced by both oil and time	50
IX. Analysis of variance of factors influencing fatty acid composition of tissue after deep fat frying	54
X. The fatty acid content of tissue samples after cooking in various oils	58
XI. The fatty acid content of tissue after using different batter recipes	61
XII. The fatty acid content of tissue samples after cooking for various time periods . .	65
XIII. The fatty acid content of tissue as influenced by both batter recipe and time .	69

LIST OF TABLES

(Continued)

TABLE		Page
XIV.	The fatty acid content of tissue as influenced by both oil and time	72
XV.	The fatty acid content of tissue as influenced by both oil and batter recipe . .	74

ABSTRACT

This experiment was conducted to study the fatty acid composition of batter coated chicken parts as affected by cooking oil, batter recipes, and time of cooking.

The fatty acid composition of the batter and tissue portions of a batter coated drumstick was used as a criterion.

The oils penetrated into and through the batter into the tissue sample. The fatty acids in the batter and two fatty acids in the tissue, linoleic and linolenic, were found to be influenced by the cooking oil. The five oils used, cottonseed, corn, peanut, lard, and a commercially mixed oil, varied in their contribution of the various fatty acids.

The factor having the greatest influence on the tissue samples was time of cooking. The only fatty acids studied which did not show an increase in concentration as time increased from two to eight and finally 14 minutes were palmitoleic, stearic, and linolenic acids, with the latter approaching significance. A significant time effect was found in the batter samples when oleic and linoleic acids were

considered.

Changing the ingredients of the batter only influenced two fatty acids, linoleic and linolenic, to any extent and these were both found in the tissue samples. The changing of the batter recipe was thought to have an effect upon the cooking oil depending upon what was excluded. The ingredients which were excluded from the complete fritter type batter were; egg, non-fat milk solids, and baking powder. These ingredients were excluded singularly because of the possibility of complicating the experiment..

INTRODUCTION

The possible changed nutritional value of fats and oils heated to high temperatures has been a concern for several years. With deep fat fried foods assuming a place of importance in the diets of many individuals, the changes which occur in the fried product as a result of frying in various fats and oils should be investigated. The various batter ingredients as they influence the absorption and/or adsorption of the oil during cooking is a factor which should be included in this study. The absorption or adsorption of fat from the cooking oils could change the fatty acid content of the product to a significant degree. This information could be used to determine the combination of cooking oils and batter recipes to be used to obtain an end product with a specific fatty acid profile. This concept will gain importance as human nutritionists determine the correct balances of fatty acids required for optimum health and growth.

The objective of this study was to determine the effects of various cooking oils, batter recipes, and times of cooking on the fatty acid content of the

batter and meat product during frying. In addition, it was desirable to determine whether the composition of the oil was changed.

REVIEW OF LITERATURE

The changes which occur in the cooking oil during deep fat frying have been of increasing interest as this method of cooking becomes more popular in the home and especially in commercial establishments. The latter is of greatest concern because of the large quantities which are fried each day and the longer periods of time the oil is used before it is discarded. Bailey (1951) noted that heating of oil under deep fat frying conditions resulted in considerable polymerization and a consequent decrease in unsaturation. Keane et al. (1959) used cottonseed oil in his research which indicated more unsaturates appear and caloric value increased as the oil was heated in a deep fat fryer, this was in opposition to the findings of Bailey (1951). Lowe et al. (1940) agrees with the conclusion of Keane et al. (1959) in their finding of increased iodine numbers under laboratory deep frying conditions which indicated an increase in unsaturation. The confusing picture was not cleared by the research of Melnick (1957) on the absence of thermal polymers and Melnick et al. (1958); in the former he found a significant 1% increase in iodine value of oils

used in commercial potato chip frying, in the latter they indicated a decrease of 3% in iodine number after frying potato chips commercially. At high altitudes using various fats and dough mixtures, Thiessen (1939) found a decrease in iodine number and smoke point when frying doughnuts. Wishner and Keeney (1956) found no change in the fatty acid composition after frying 3400 g. potatoes for one hundred minutes.

Thermally induced changes in fats used for deep fat frying include hydrolysis, polymerization, and oxidation as was reported by Carlin et al. (1954). Robinson et al. (1940) while studying the foaming tendencies in edible oils and fats noted thermal decomposition evidenced by increased refractive indices, lowered active oxygen values, and increased viscosity after preheating periods at 191°C. A number of objectionable developments including loss of rancidity resistance, color and flavor changes, a drop in oxidative stability, reduction in keeping quality of potato chips, foaming tendencies, increase of saponification number and refractive index were found by Carlin and Lannerud (1941). Thermal oxidation of corn oil at 200°C. caused the formation of polymeric material with molecular weights ranging from 692 to 1,600. These polymers

were of high oxygen content and contained unsaturation difficult to remove by hydrogenation, the oxygen was found to be in the form of hydroxyl and carbonyl groups, as reported by Perkins and Kummerow (1959). The attack of oxygen was found to take place at the methylene group adjacent to the double bond with the formation of conjugated hydroperoxides, evidence indicated the attack to occur at carbon nine and 13. Decomposition of these hydroperoxides could result in polymerization or oxidation. Perkins and Van Akkeren (1965) found that polymeric material increased regularly as time increased when cottonseed oil was intermittently heated and cooled as would be the case under commercial conditions. While studying the chemical and physical properties of fats and oils commercially used for deep fat frying, Thompson et al. (1957) could account for only 84% of the fatty acids by gas chromatography due to presence of polar and polymeric fatty acids. In addition to thermal polymerization Perkins (1960) found autoxidation and thermal oxidation. Brown (1959), while studying changes in nutritive value of food fat during processing and cooking, noted no important chemical changes take place while heating fats below 200°C. in the absence of oxygen for a reasonable length of

time. At ordinary temperature in the presence of air, oxidation occurs with the formation of hydroperoxide which may be toxic. The hydroperoxide can either decompose with rupture of the chain or can rearrange to give hydroxylated compounds and eventually polymers. The opposite view was presented by Melnick (1957), in his work on absence of thermal polymers in potato chip frying oils and Melnick et al. (1958) in whose experiments no thermal polymers were found to occur in potato chip frying oils. Frazer (1964) found three main groups of products of oxidation at cooking temperature; first hydroperoxides, second the secondary oxidation products such as carbonyl compounds, epoxy and hydroxy fatty acids, and third the cyclic fatty acids and polymers. Rapid hydrolysis of fats when held at a temperature of 193°C . in the presence of a constant flow of steam was reported by Lantz and Carlin (1938). Hydrolysis was reported as being slow during the first twenty hours of heating but rapidly accelerated after free fatty acid levels of 0.5 to 1.0% were reached. This observation coincides with actual production experiences of manufacturers of fried foods from which large amounts of water must be evaporated. Perkins and Van Akkeren (1965) noted a strong deteriorative effect on heated

cottonseed oil with the simple addition of water which apparently led to hydrolysis.

The amount of decomposition was demonstrated to be indicated by an increase in the free fatty acid content and a decrease in the smoke point by Bennion and Hanning (1956a). The free fatty acid content as oleic acid was increased, the smoke point lowered, and the color darkened as a result of using oil to cook doughnuts, as reported by Lowe et al. (1958). The cause of these changes were not determined specifically but a conclusion of individual effects as well as interactions between the various factors were determined to be the causes. Lantz and Carlin in 1938 reported that highly hydrogenated fats develop free fatty acids at more rapid rates than do the less saturated fats at temperatures of 193°C . Cooking with oil resulted in a decrease in the polyenoic fatty acid concentration of the oil as reported by Fleischman et al. (1963). Heating alone was found to be at least partial cause of this decrease although not necessarily the entire cause. Kritchevsky et al. (1961), studying the effects of absence or presence of fatty vehicle on atherosclerosis, found an increase of titratable fatty acid in corn oil if heated for ten minutes at $160-200^{\circ}\text{C}$.

A different conclusion was presented by Melnick et al. (1958) as a result of studying the composition and control of potato chip frying oils in continuing commercial use, they found no greater than 0.6% free fatty acids.

The product fried in the various oils appears to have an effect on the changes found after frying. Bennion and Hanning (1956a) studying the decomposition of lard in the frying of French fried potatoes and of fritter type batters found the frying of the fritter batter caused a greater degree of decomposition than did the potatoes. This was indicated by a more pronounced increase in free fatty acid content, a decrease in the smoke point, darkening of the fat, and a generally undesirable appearance. Peroxide values remained at lower levels when the batter was fried instead of potatoes, the iodine number and saponification number were little affected in either case. Baking powder, milk, and eggs appeared to be the ingredients in batter exerting the greatest influence on the decomposition of lard. Fat absorption was noted to decrease in absence of the leavening agents. Bennion and Hanning (1956b) studied the addition of monoglycerides to continuous process lard to be used in frying French fried potatoes.

The smoke point was lowered and fat absorption was not increased by the addition of the monoglycerides.

Thiessen (1939) studying various fats used in deep fat frying of dough mixtures at high altitudes found no difference in absorption using four different fats. A decrease was reported by Kilgore and Luker (1964) in linoleic acid from 57 to 49% in cottonseed oil used ten hours for frying chicken or potatoes. Their work indicated no change in linoleic acid content when chicken was fried in lard but a decrease of 11.3 to 5.8% was noted after frying potatoes for ten hours.

The nutritional quality of the fats and oils has been gaining much attention as the cause of various diseases concerned with lipid metabolism of the human are discovered. Thompson et al. (1967) in a limited survey of fats and oils commercially used for deep fat frying analyzed their physical and chemical properties. This study indicated the degree of deterioration depends on how they are used by the processors. The method of care has much to do with the frying life of the fat according to Rust and Harrison (1960), the viscosity, percent weight loss of the fat as well as the potatoes were also affected by method of care. Poling et al. (1962) in a study using cottonseed oil to examine the

influence of temperature, heating time, and aeration upon the nutritive value of fats, found changes are proportional to the severity of the conditions.

Keane et al. (1959) did biological and chemical studies on commercial frying oils and found no deleterious effects on rats fed cottonseed oil heated for 24 days in a commercial deep fat fryer at dietary levels as high as 20 percent. The heated oils were found to have an increased caloric value when compared to the unheated oil, this was attributed to an increase of unsaturation in the fats. The fats heated under laboratory conditions yielded a lower growth rate in rats than unheated but no toxicity appeared. Melnick (1957) in a study on the absence of thermal polymers in potato chip frying oils used commercially heated fats from potato chip frying operations and could show no detrimental effects attributable to heated fat. Also in 1957, ~~in a study on~~ nutritional quality of frying fats in commercial use, the above mentioned researcher in a nation wide survey could find no nutritional damage to the fat under normal processing or cooking conditions. This conclusion by Melnick was supported by a nutritive study by Rice et al. (1957a) which showed no detrimental effects on commercially heated fat. Melnick et al. (1958)

again showed no nutritional value change in fats used in continuing commercial operation.

The various changes the fats and oils undergo during cooking is of importance not only to the consumer but the producer of oil and food products which must have consumer acceptance and appeal before they can be marketed successfully. The absorption and/or adsorption of various substances from the cooking medium by the product certainly is an important aspect of the problem.

The fatty acid content of meat and poultry before and after cooking was determined by Chang and Watts (1952). The method of cooking was one which did not include cooking oil and any liquid cooking from the meat was efficiently drained away. The fatty acid content as analyzed by spectrophotometric techniques indicated only a small amount of the polyunsaturated fatty acids were lost due to method of cooking. Weir et al. (1962) disagreed with this finding and concluded a change occurred in the cooked meats as result of method of cooking. A comparison of broiler fryers fried by three methods was made by Smith and Vail (1961) in which the three methods studied were skillet, deep fat, and oven frying. The deep fat

fried product had a higher percent of fat than the other methods tested. A study conducted by Woodruff and Blunt (1919) indicated that both temperature and length of frying time determined the amount of fat taken up by dough samples. The longer time and lower temperatures gave the most absorption. Fat absorbed by the product underwent greater chemical changes than fat in which the product was fried. Lard showed more decomposition than did Wesson oil.

The importance of the dough recipe on fat absorption in frying doughnuts was illustrated by McKee (1918). By varying the recipe a marked difference in fat taken up was noted. Egg increased fourfold the ether soluble content of the dough and a decrease in the total fat of the doughnut after frying. This may have been due to the addition of 200 grams of flour to stiffen the dough. Doubling and the increasing fourfold of the fat in the recipe increased the absorption of fat greatly in excess of added fat. Doubling the sugar content of the recipe also gave an increase in the fat content. The relative values of various lards and other fats used in deep fat frying of potato chips were studied by King et al. (1936). These workers found an increased free fatty acid content present in fat extracted from the potato

chips than was present in the frying oil. Fisher (1949) found a correlation between the thermally developed free fatty acids of frying fats and the physical characteristics and fat absorption properties of doughnuts. Although the fats reported by Fisher did not develop free fatty acids above the level of 0.40%, he recognized as a possibility the influence of other thermally formed constituents in the frying fat. Goodman and Block (1952) studying problems encountered in commercial utilization of frying fats noticed drastic changes in the shape, crust character, and fat absorption properties of doughnuts. Those doughnuts showing the changes were fried in fats subjected to prolonged heating at 191°C. Thermally formed substances in the fat were evidenced by increased free fatty acid content and greatly reduced iodine numbers. Chung et al. (1966) studied changes in fatty acids in beef, pork, and fish after deep fat frying in different oils. The oils used were corn, peanut, and lard. Beef, pork and fish all lost more weight when broiled than when deep fat fried but more fat was lost in the broiled meat. The difference was discovered to be the uptake of oil from the cooking medium when deep fat fried. The water content was greater when broiled but the fat content was less. The cooking oils changed very little under deep fat

frying conditions. The fish fried in peanut oil and lard caused an increase in 20:0, 20:1 and 20:4 fatty acids in the frying medium, apparently due to infiltration from the fish. The beef, pork, and fish showed an increase in 18:2 fatty acid when cooked in corn oil, peanut oil and lard. The greatest increase was found to be with corn oil, peanut oil was second. A decrease in 14:0 and 16:0 fatty acids with all three oils, a decrease in 18:0 fatty acid with corn oil and peanut oil was noted in fish and beef. The pork sample was unchanged in respect to the 14:0 and 16:0 fatty acid content.

EXPERIMENTAL PROCEDURE

Frying Operation

One hundred and twenty chicken drumstick parts were obtained from a commercial retail establishment and randomly divided into five groups. Six of these parts were immersed in one of four batters, removed and allowed to drip for thirty seconds prior to placing in the hot oil. This was done to ensure a uniform distribution of the batter on the chicken part. These batter coated parts were then immersed in cooking oil maintained at $188^{\circ} \pm 3^{\circ}\text{C.}$, two being removed after each of three time periods. The frying times of two, eight and 14 minutes were decided from preliminary experiments and guidelines established in the Department of Poultry Science, Louisiana State University. A Sunbeam automatic cooker and deep fryer containing 1800 ml. of cooking oil was used to fry the parts. The temperature regulation mechanism was determined not to be adequate for this operation and a thermometer calibrated in 0.5°C. was placed in the oil to aid in maintaining a correct and constant temperature. After cooking, the chicken parts were removed using a forcep and placed in a wire basket to drain at room temperature for a period of three

minutes. The batter and meat were separated from the bone and each other, placed in separate containers and immediately placed in a deep freeze to solidify the oil and reduce oxidation to a minimum. A sample of the cooking oil was taken before and after frying to determine if any fatty acid changes had taken place. The deep fat fryer was then emptied of oil, washed, dried and filled with 1800 ml. of new oil. It was desirable to use fresh oil for each of the different batters to prevent generating artifacts due to possible changes in the oil after the dipping operation.

Batters

The batter used was a basic fritter type which can be found in most good cook books and has been used by many experimenters in deep fat frying. The ingredients were 168.0 g. all purpose flour, 45.0 g. sugar, 5.0 g. salt, 3.8 g. tartrate baking powder, and 6.5 g. commercially prepared instant non-fat milk solids sifted together and blended with a mixture of 90.0 g. whole egg and 79.0 g. distilled water. Each batch was mixed fresh for each oil because of the changes which could occur due to the dipping of the

chicken part.

In order to study the influence of the different ingredients on changes in the fatty acid penetration of the batter and chicken part, and changes which could occur in the oil, the following alterations were made in the basic batter mentioned above.

1. Complete (as described above)
2. Complete minus whole egg
3. Complete minus non-fat milk solids
4. Complete minus baking powder

Additional comparisons could be made by removing combinations of the above but it was decided that this would lead to complication of the experiment to such a degree that much of its value might be lost.

Oils

The oils used were: Mazola Pure Corn Oil, Corn Products Company, New York, N.Y.; Perfecto Peanut Oil, Opelousas Oil Refinery, Opelousas, La.; Autocrat Unique Salad Oil, from selected vegetable oils (mixed oil), Associated Distributing Co., Inc., New Orleans, La.; Mar-Gold Salad Oil, pure cottonseed oil, Atlanta, Ga., and Swifts Silverleaf Brand Pure Lard, Chicago, Ill.

A preliminary analysis determined the selection of the oils for the following reasons. Lard was high in the saturated fatty acids, especially myristic, palmitic, and stearic, it also had large amounts of oleic and to a lesser degree, linoleic. Corn oil was found to be high in linoleic with much lower amounts of palmitic acid. Cottonseed oil had less palmitic and oleic but comparatively large amounts of linoleic acid. Peanut oil was low in the saturates when compared to lard and high in oleic and linoleic acids. A commercially mixed oil was also used because it appeared to have a medium level of each of the fatty acids. By using these five oils, meaningful conclusions might be drawn when comparing the absorption and/or adsorption of fatty acids.

Before and after frying samples of oil were taken to determine if any changes occurred in the oil due to the possibility of acids, water, or other constituents entering or leaving the meat and batter during the frying operation. These samples were placed immediately in a deep freeze to reduce oxidation to a minimum.

Chemical Analysis

The batter and tissue samples remained frozen until just prior to extraction at which time both sample and total weights were determined. The weighed samples were extracted using 20 ml. of 2:1 chloroform - methanol (v/v) mixture per gram of tissue. A Waring Blendor with the micro-container attachment was used to reduce the tissue and batter to a size at which maximum extraction could occur. This was accomplished using a variable voltage meter attached to the blendor to give a voltage of 35% of maximum, this gave maximum extraction with no loss of sample. The sample was filtered into a tared 250 ml. boiling flask, evaporated on a vacuum flash evaporator at 40°C. until only a semisolid appeared adhering to the walls of the flask. The flask plus the contents were weighed and the weight of the extractant determined and labeled total lipid.

The total lipid was then saponified by the method of Teekell, (1968), in which the samples were refluxed for one hour in alcoholic KOH, the non-saponifiable fraction removed using petroleum ether, the fatty acids acidified with HCL and separated using petroleum ether. This fraction was weighed and referred to as total fatty acids. The sample of fatty acids was taken up in 5 ml.

of methanol and esterified by heating at 65°C. for two hours after adding 0.25 ml. H_2SO_4 and 0.20 ml. dimethoxypropane by the method of Teekell (1968). The methyl esters which resulted from this procedure were removed using hexane then taken to dryness in preparation for analysis on a gas chromatograph.

The fatty acids analyzed on the gas chromatograph were: Myristic, C_{14} ; Palmitic, C_{16} ; Palmitoleic, $C_{16:1}$; Stearic, C_{18} ; Oleic, $C_{18:1}$; Linoleic, $C_{18:2}$; and Linolenic, $C_{18:3}$. The separation was accomplished on a Microtek Model 220 Gas Chromatograph equipped with a dual hydrogen flame detector. The six foot column was packed with 15% diethylene glycol succinate, 2% orthophosphoric acid on 60-80 mesh Chromosorb W (Teklab, Inc., Baton Rouge, La.) with methylene chloride as the solvent. Methyl ester standards (Microtek Instruments Corporation, Baton Rouge, La.) were used for identification as well as quantitating the individual fatty acids.

Statistical Design And Analysis

Three main variables were studied; type of cooking oil, batter recipe, and time of cooking, in relation to their effect on the amount of fatty acid penetration into the batter and chicken part. The interactions of

the main effects were also important and were analyzed statistically. To detect differences between the main effects and their interactions, a split plot arrangement of treatments on a randomized block design was used. Orthogonal comparisons were used to separate the degrees of freedom. The data were analyzed using the analysis of variance technique as outlined in Steel and Torrie (1960).

RESULTS AND DISCUSSION

The purpose of this study was to determine the effects of various cooking oils, batter recipes, and times of cooking on the fatty acid content of the batter and meat product during frying. In addition, it was desirable to determine whether the composition of the oil was changed.

Batter Samples

Cooking Oil

An analysis of the various batter samples was conducted to determine the amounts of myristic, palmitic, palmitoleic, stearic, oleic, linoleic, and linolenic acids present. The analysis of variance of the data for each of the fatty acids is presented in Table I. Significant differences were noted between the cooking oils used when the amount of each of the various fatty acids were analyzed. This indicated each of the oils were absorbed and/or adsorbed to the batter and different levels of the fatty acids measured were found depending upon which oil was used. This difference might be anticipated when the fatty acid distribution of the cooking oils are considered. Table II shows the distribution of fatty acids in a sample of oil before it was used to fry the batter coated chicken

TABLE I

ANALYSIS OF VARIANCE OF FACTORS INFLUENCING FATTY
ACID COMPOSITION OF BATTER USED IN DEEP FAT
FRYING OF CHICKEN

Myristic Acid				
Source	D.F.	S.S.	M.S.	F
Total	119	59.65		
Oil (A)	4	37.62	9.40	44.32**
4 vs 1,2,3,5	1	37.50	37.50	178.56**
1,5 vs 2,3	1	0.32	0.32	1.52
2 vs 3	1	0.001	0.001	0.005
Batter (B)	3	0.85	0.28	1.33
A x B	12	2.79	0.23	1.09
Error a	20	4.24	0.21	
Time (C)	2	0.29	0.15	0.93
B x C	6	1.71	0.29	1.86
A x C	8	1.01	0.13	0.82
A x B x C	24	5.00	0.21	1.36
Error b	40	6.15	0.15	
Palmitic Acid				
Total	119	12,270.32		
Oil (A)	4	4,361.29	1,090.33	27.53**
4 vs 1,2,3,5	1	4,271.18	4,271.18	107.86**
1,5 vs 2,3	1	34.56	34.56	0.87
2 vs 3	1	53.43	53.43	1.35
Batter (B)	3	126.33	42.11	1.06
A x B	12	935.00	77.92	1.97
Error a	20	792.03	39.60	
Time (C)	2	319.18	159.59	2.93*
B x C	6	924.67	154.11	2.83*
A x C	8	188.27	23.53	0.43*
A x B x C	24	2,447.42	101.98	1.87*
Error b	40	2,176.15	54.40	

Continued

TABLE I
(Continued)

Palmitoleic Acid

Source	D.F.	S.S.	M.S.	F
Total	119	4,702.72		
Oil (A)	4	2,517.41	629.35	98.05**
4 vs 1,2,3,5	1	2,513.00	2,513.00	391.57**
1,5 vs 2,3	1	3.02	3.02	0.47
2 vs 3	1	1.01	1.01	0.16
Batter (B)	3	37.62	12.54	1.95
A x B	12	148.31	12.36	1.93
Error a	20	128.37	6.42	
Time (C)	2	13.49	6.75	0.31
B x C	6	210.12	35.02	1.62
A x C	8	62.14	7.77	0.36
A x B x C	24	717.95	29.92	1.38
Error b	40	867.31	21.68	

Stearic Acid

Total	119	4,837.67		
Oil (A)	4	2,771.89	692.97	76.79**
4 vs 1,2,3,5	1	2,596.84	2,596.84	287.90**
1,5 vs 2,3	1	142.87	142.87	15.84**
2 vs 3	1	28.46	28.46	3.15*
Batter (B)	3	61.02	20.34	2.25
A x B	12	167.78	13.98	1.55
Error a	20	180.48	9.02	
Time (C)	2	37.27	18.64	1.91**
B x C	6	267.34	44.56	4.58**
A x C	8	118.93	14.87	1.53**
A x B x C	24	843.70	35.15	3.61**
Error b	40	389.26	9.73	

Continued

TABLE I
(Continued)

Oleic Acid				
Source	D.F.	S.S.	M.S.	F
Total	119	74,410.44		
Oil (A)	4	17,012.50	4,253.13	14.64**
4 vs 1,2,3,5	1	1,926.73	1,926.73	6.63*
1,5 vs 2,3	1	1.22	1.22	0.004**
2 vs 3	1	8,644.63	8,644.63	29.76**
Batter (B)	3	755.50	251.83	0.87
A x B	12	2,594.61	216.22	0.74
Error a	20	5,808.87	290.44	
Time (C)	2	4,132.76	2,066.38	4.13*
2 vs 8,14	1	1,865.95	1,865.95	3.73
8 vs 14	1	2,268.45	2,268.45	4.53*
B x C	6	7,011.89	1,168.65	2.33*
A x C	8	3,826.14	478.27	0.95
A x B x C	24	13,234.52	551.44	1.10
Error b	40	20,033.76	500.84	

Linoleic Acid				
Total	119	454,690.25		
Oil (A)	4	177,152.56	44,288.41	254.41**
4 vs 1,2,3,5	1	126,041.19	126,041.19	72.40**
1,5 vs 2,3	1	14,072.79	14,072.79	8.08*
2 vs 3	1	23,348.31	23,348.31	13.41**
Batter (B)	3	3,855.75	1,285.25	0.74
A x B	12	40,107.25	3,342.27	1.92
Error a	20	34,816.78	1,740.84	
Time (C)	2	29,917.70	14,958.85	9.81**
2 vs 8,14	1	15,876.27	15,876.27	10.41**
8 vs 14	1	14,045.00	14,045.00	9.21**
B x C	6	21,460.03	3,576.67	2.34*
A x C	8	21,662.82	2,707.85	1.78
A x B x C	24	64,699.35	2,695.81	1.77*
Error b	40	61,018.22	1,525.46	

Continued

TABLE I
(Continued)

Linolenic Acid				
Source	D.F.	S.S.	M.S.	F
Total	119	170,056.31		
Oil (A)	4	84,867.88	21,216.97	27.01**
4 vs 1,2,3,5	1	16,111.03	16,111.03	20.51**
1,5 vs 2,3	1	53,865.38	53,865.38	68.56**
2 vs 3	1	11.52	11.52	0.01
Batter (B)	3	1,599.91	533.05	0.68
A x B	12	5,406.64	450.55	0.57
Error a	20	15,713.59	785.68	
Time (C)	2	2,528.65	1,264.33	1.74
B x C	6	4,798.75	799.79	1.10
A x C	8	8,182.74	1,022.84	1.41
A x B x C	24	17,994.93	749.79	1.04
Error b	40	28,960.08	724.00	

** Significant at the 0.01 level of probability

* Significant at the 0.05 level of probability

Orthogonal Comparisons

Oils

- 1 = Cottonseed
- 2 = Corn
- 3 = Peanut
- 4 = Lard
- 5 = Mixed

Times

- 2 = two minutes
- 8 = eight minutes
- 14 = fourteen minutes

TABLE II

THE DISTRIBUTION OF FATTY ACIDS IN VARIOUS COOKING
OILS BEFORE AND AFTER USE

Batter	Cottonseed oil (mg./g.)						
	C ₁₄ [*]	C ₁₆	C _{16:1}	C ₁₈	C _{18:1}	C _{18:2}	C _{18:3}
0	0.1**	34.6	2.1	14.1	84.5	492.7	340.0
1	0.1	38.3	0.8	10.1	75.3	413.2	360.0
2	0.1	30.1	4.7	21.2	91.3	450.1	369.4
3	0.1	42.7	17.2	14.7	88.8	437.2	237.0
4	0.1	32.5	6.3	18.7	89.2	477.1	360.5
Corn Oil							
0	0.1	59.8	3.7	8.0	125.3	683.9	41.2
1	0.1	63.3	3.5	17.4	150.2	663.7	38.7
2	0.1	66.3	3.3	11.0	159.2	747.9	45.1
3	0.1	65.5	3.2	17.6	163.8	779.1	33.2
4	0.1	64.8	4.4	10.0	142.8	743.2	56.0
Peanut Oil							
0	0.1	68.6	4.3	18.4	332.0	459.8	68.9
1	0.1	67.0	6.3	18.7	330.5	458.5	77.5
2	0.1	78.1	7.1	16.3	317.8	402.9	48.0
3	0.1	84.5	6.5	13.4	305.3	409.5	45.3
4	0.1	75.8	3.0	19.6	322.9	433.8	74.6
Lard							
0	9.2	219.0	100.3	84.7	347.1	134.4	17.2
1	7.6	216.7	91.4	76.4	335.1	156.1	23.5
2	9.2	182.3	82.9	90.8	346.8	129.3	22.5
3	9.6	168.8	75.7	87.3	278.8	138.9	23.3
4	13.6	196.2	100.1	92.5	367.4	155.9	24.7

Continued

TABLE II
(Continued)

Mixed Oil

Batter	C ₁₄	C ₁₆	C _{16:1}	C ₁₈	C _{18:1}	C _{18:2}	C _{18:3}
0	0.1	67.5	3.4	22.0	271.0	508.9	137.1
1	0.1	62.0	4.9	25.4	261.4	491.6	151.7
2	0.1	57.3	5.9	26.3	215.1	501.3	91.1
3	0.1	56.1	6.1	25.8	257.4	485.9	148.4
4	0.1	65.8	4.4	23.8	261.1	466.4	148.1

* Numbers in this column are less than 0.1 with the exception of lard.

** Each value appearing in this table represent one analysis on pooled samples of oil intended for compositional analysis to indicate further experimental areas. This data does not lend itself to completely satisfactory statistical analysis but due to the possibility of trends occurring which could help explain other data it was included.

Batters

0 = Oil prior to use as cooking medium

1 = Complete batter

2 = Minus egg

3 = Minus non-fat milk solids

4 = Minus baking powder

parts. Myristic acid was present only in the unused lard sample to any extent, the other oils having less than 0.1 mg. per g. of oil. The same trend was noted in the case of palmitic acid as it was found in substantially higher quantities from the lard than was noted from the other oils. Palmitoleic acid and stearic acid were also found to follow the trend exhibited by palmitic acid. The levels in lard might be expected because all four of these fatty acids occur in comparatively large quantities in mammalian tissues, especially the adipose tissue. Oleic acid appeared to be present in lard, peanut, mixed, and corn oils in decreasing amounts with lard being the most prominent. Cottonseed oil seemed to be comparatively lower than the ones mentioned above. Linoleic acid content was less in the lard sample than the other oils according to the figures in Table II. Linolenic acid appears to be higher in cottonseed oil with less present in the mixed oil, the remaining oils were found to be less when compared to either the cottonseed or mixed oils. The distribution shown in Table II may indicate that differences in the amounts of fatty acids in the sample could depend upon the levels of the respective fatty acids in the cooking oil. This could be the case only if the various batters

have no effect and the fats are absorbed at the same rate from the cooking medium. Because the data cannot be satisfactorily statistically analyzed, as seen at the bottom of Table II, definite statements cannot be made concerning this table. The fatty acid content of the batter samples after cooking in various oils are listed in Table III. No attempt was made to differentiate the amount of free fatty acids which may have been absorbed and/or adsorbed. These fatty acids could make a difference and should be taken into account in the future. The myristic acid level was highest by a large amount when lard was used as the cooking medium, this could be expected because of the larger amounts of this fatty acid occurring in lard. The use of lard has also resulted in a large difference in palmitic, palmitoleic, and stearic acid levels as could be predicted from levels of these fatty acids in the cooking oil. The stearic acid levels in the batter also show marked differences when the use of corn oil was compared to peanut oil and both of these when compared to cottonseed and mixed oils. The oleic acid content of the batter was expected when cottonseed oil and corn oil were compared to peanut, lard, and mixed oils in which the oleic acid content was at a much higher level of content

TABLE III
THE FATTY ACID CONTENT OF BATTER SAMPLES AFTER
COOKING IN VARIOUS OILS

Oils	Fatty Acid (mg./g.)						
	C ₁₄	C ₁₆	C _{16:1}	C ₁₈	C _{18:1}	C _{18:2}	C _{18:3}
1	0.32	15.80	3.33	5.49	35.52	142.82	75.07
2	0.26	13.63	4.01	2.61	33.46	123.77	10.58
3	0.25	15.74	3.72	4.15	60.30	79.66	9.60
4	1.71	30.20	15.13	16.23	57.01	32.80	4.81
5	0.42	15.97	3.69	6.15	58.69	109.04	39.86

Cooking Oils

- 1 = Cottonseed
- 2 = Corn
- 3 = Peanut
- 4 = Lard
- 5 = Mixed

in both Tables II and III. Linoleic acid was present in cottonseed, corn, and mixed oils in amounts in excess of 100 mg./g. of batter while peanut oil contributes only approximately 80 mg. and lard only 33 mg./g. of batter. Linolenic acid content showed an interesting picture due to the differences noted between some of the oils. Cottonseed oil and mixed oil were contributors of the largest amount of this fatty acid which were 75 and 40 mg. respectively while corn, peanut, and lard contributed lesser amounts of 11, 10, and 5 mg. respectively.

Orthogonal comparisons were run as seen in Table I for each of the oils in an attempt to partition the degrees of freedom. The comparisons were decided upon prior to the experimental analysis to compare animal versus vegetable oils (4 vs 1,2,3,5), cottonseed and mixed oils versus corn and peanut oils (1,5 vs 2,3), and corn oil versus peanut oil (2 vs 3). A highly significant difference for the first comparison, animal versus vegetable, was found to exist for myristic, palmitic, palmitoleic, stearic, linoleic and linolenic acids. A significant difference (0.05 level of probability) was found for oleic acid. This evidence plus that already presented indicated a

definite difference does exist between the two sources of cooking oil. The comparison of cottonseed and mixed oils versus corn and peanut oils showed a highly significant difference (0.01 level of probability) existing when palmitic and stearic acids were examined and a significant difference when linoleic acid was examined. The data presented in Table III indicates the contribution of cottonseed oil and mixed oil in the batter was greater than the other two oils when the three fatty acids found significant were totaled. With the exception of linoleic, this indicated that these two oils contributed more saturated fatty acids than did the other two. The last comparison, corn oil versus peanut oil, was made to try and separate this even farther. A highly significant difference was found in the case of oleic, linoleic, and linolenic acids with a significant difference found with stearic acid. Corn oil was found to be significantly less than peanut in its contribution to the batter of stearic and oleic acids and higher in linoleic and linolenic acids. Corn oil contributed less saturates than any of the five oils considered followed by peanut, cottonseed, and mixed oils with lard having by far the largest amount. This was not the order

suggested by the relative amounts in the unused oils where cottonseed oil would appear to contribute less than corn oil.

Time

The fatty acid content of the batter was affected significantly by time only in the case of oleic and linolenic acids as shown in Table I. Table IV shows both of these fatty acids had an increase in amount in the batter as time increased. Oleic acid increased from a low of 43.4 mg./g. of batter after two minutes frying time to 46.5 and 57.1 mg./g. for eight and 14 minutes respectively. Linoleic acid levels appeared to increase from 81.4 to 92.5 mg./g. and finally 119.0 mg./g. for the time periods of two, eight, and 14 minutes respectively. The greatest increase in both cases occurs between the eight and 14 minute periods where an increase of 11 and 27 mg./g. of batter was noted for oleic and linoleic acids respectively.

Orthogonal comparisons were run on these two fatty acids to determine if one time period had a greater influence on the amount of fatty acid present than the other. Linoleic acid demonstrated a highly

TABLE IV
THE FATTY ACID CONTENT OF BATTER SAMPLES AFTER COOKING
FOR VARIOUS TIME PERIODS

Time (Min)	Fatty Acid (mg./g.)						
	C ₁₄	C ₁₆	C _{16:1}	C ₁₈	C _{18:1}	C _{18:2}	C _{18:3}
2	0.55	16.70	5.51	6.14	43.42	81.35	28.52
8	0.56	17.58	6.12	7.24	46.46	92.50	22.12
14	0.66	20.52	6.29	7.40	57.11	119.00	33.32

significant difference when two minutes was compared to eight and 14 minute time periods and between the eight and 14 minute periods. Oleic acid had a significant difference between eight and 14 minute periods with none when two was compared to eight and 14 minute periods. This leads to the conclusion that only in these two cases was fatty acid content increased over the time periods studied. The others have reached their maximum absorption at the end of two minutes and 12 additional minutes makes little difference. Both of these acids are unsaturated, oleic at the 9 position and linoleic at the 9 and 12 positions, and both are 18 carbons in length. From this evidence it was possible to theorize that perhaps the batter composition of these fatty acids was affected by time because of an effect of chain length or unsaturation. One observation which may make this hypothesis less valid was that palmitic acid, a 16 carbon saturated acid, approached significance very closely when examined for the three time periods. The cooling times could possibly be a factor to be included in this discussion because the part heated for the longer period would take longer to cool and give the oil more time to penetrate the sample. The possibility of

lowering of melting points, due to double bonds, having an influence on time of exposure to the batter coated chicken part and the amount absorbed cannot be considered possible from this evidence.

Batter Recipe

The hypothesis of no difference between means was determined to be true in the case of different batter recipes and their effects on the amount of oil removed from the cooking medium as seen in Table I. The means are presented in Table V for comparison. This result was expected to be significant in all cases. The hypothesis under which this experiment was designed was that significant differences would occur depending on the batter recipe. The reasoning for this was based on two factors primarily, the first that by removing the baking powder from the recipe and second by altering the other ingredients a difference in fatty acid content could be found. The removal of the baking powder was expected to reduce the surface area of the batter and consequently reduce the surface area to which the oil could be absorbed and/or adsorbed. This was apparently not the case and the absorption and/or adsorption remained

TABLE V

THE FATTY ACID CONTENT OF THE VARIOUS BATTERS
AFTER COOKINGFatty Acid
(mg./g.)

Batter	C ₁₄	C ₁₆	C _{16:1}	C ₁₈	C _{18:1}	C _{18:2}	C _{18:3}
1	0.54	18.25	5.65	7.88	50.88	107.25	25.40
2	0.74	19.69	6.91	7.34	51.81	96.08	26.21
3	0.55	18.35	5.87	6.18	45.49	93.03	34.29
4	0.54	16.79	5.47	6.31	47.81	94.11	26.04

Batters

- 1 = Complete
- 2 = Minus egg
- 3 = Minus non-fat milk solids
- 4 = Minus baking powder

the same. The removal of whole egg and non-fat milk solids were selected because of their high fat content and lack of fat respectively, the removal of these ingredients was expected to have an influence on the fatty acid profile in the batter. This again proved to be a false assumption. A possible explanation for these results could be based on the fact that the amount of batter on the chicken part was a small part of the whole, when the amount of cooking oil (1800 ml.) was considered. The increased amount of fatty acids contributed by the oil would completely hide any effect of the batter recipe.

The effect of batter recipe on cooking oil may be determined by comparing the samples removed after cooking the various batter coated chicken parts to the unused oil. These results are presented in Table II.

Cottonseed Oil

The oil used to cook the complete batter compared to the unused oil was associated with small if any differences being discovered in cottonseed oil after use, with the possible exception of palmitoleic acid where a decrease of more than 50% was noted. The removal of egg from the batter was associated with

several apparent increases of fatty acids in the oils. An additional factor of concern here was the additional amounts of water added to the batter when egg was removed to maintain a uniform consistency of the batter. The removal of non-fat milk solids caused an increase in palmitoleic acid and a possible decrease in linoleic acid of 55 mg., a larger decrease was found when linolenic acid was considered of approximately 100 mg. The removal of the baking powder had little influence on the fatty acid composition of the oil with the possible exception of palmitoleic acid.

Corn Oil

The various changes in the batter recipes had in most cases very little influence on the fatty acid content of the batter after cooking. The complete batter showed what was considered a definite increase only in stearic acid and oleic acid where 9.4 and 24.8 mg./g. increases, respectively, were noticed (Table II). With the exception of palmitoleic and myristic acids, all the remaining fatty acids appear to increase upon the removal of egg from the batter. With the added exception of linolenic acid the same conclusion was observed when non-fat milk solids were

removed. When baking powder was removed an across the board increase was noticed to occur with the exception of myristic acid, the true significance of these changes cannot be determined without a statistical analysis.

Peanut Oil

The complete batter resulted in a possible increase in palmitoleic acid only, the remaining fatty acids maintained approximately the same proportions. With egg removed a different result was observed with a trend of increases in palmitic and palmitoleic acids and decreases in stearic, oleic, linoleic, and linolenic acids being possible. The same was true when non-fat milk solids were removed. Upon removal of baking powder palmitic, linolenic, and to a lesser degree stearic acids were increased with decreases found in the comparative amounts of palmitoleic, oleic, and linoleic, again the significance of these changes are in doubt because a statistical analysis was not run on this data.

Lard

The fatty acids in the oil were influenced by

changes in the batter fried in them only to a small degree if at all. Possible decreases from the fatty acid composition of the unused oil were found when egg was removed from the batter in the case of palmitic and palmitoleic acids, the same trend was noticed when the non-fat milk solids were removed. Possible increases were found in the case of linoleic acid when the complete batter and batter with baking powder removed were used to coat the chicken part. An increase was also possible when baking powder was removed and myristic acid levels considered.

Mixed Oil

Possible decreases were noted for palmitic acid when egg and non-fat milk solids were removed, oleic acid and linolenic acid when egg was removed and linoleic acid when baking powder was removed. A trend of increases was discovered when linolenic acid levels are considered with the exception of the levels when egg was removed.

Due to visual observation of the used oil when compared to the unused oil it was apparent that some of the batter was becoming detached from the sample and contaminating the oil giving it a darkened

granular appearance. This darkened color was most apparent in the oil in which batter including non-fat milk solids were present. This could cause a dilution or enhancement of the oil depending on the fatty acid content of the various ingredients of the batter and fatty acid content of the oils. The removal of the commercially prepared non-fat milk solids from the batter in most cases had little effect, with some exceptions noted. The fact that these solids are low in fat would indicate that the amount of fatty acids they would contribute would be near zero and any removal of batter from the sample would only be influenced by non-fat milk solids in their ability to dilute the oil. No attempt was made to adjust the batter sample when this ingredient was omitted and because of this a more concentrated fat content could be expected to be the case. Also the same amount of water was used with no apparent change in the consistency of the resulting batter, but undoubtedly the batter was to some degree less viscous. Therefore, less batter would be exposed to the cooking oil but at the same time an increase in the amount of detached batter may occur due to the loss of adhesiveness. The amount of batter exposed was increased when it is realized

that the 1800 ml. of oil was exposed to batter coated parts for the three time periods and for this reason the batter was in contact with the oil for longer periods. The cooking of the three time periods at the same time interval was also the reason a split plot analysis was necessary. This increases the likelihood of batter fat moving into the cooking oil but not being found when fat movement into the batter is examined. The removal of the more volatile fatty acids could have a concentrating action on the other fatty acids.

Interactions

Table I shows a significant batter x time interaction for palmitic acid, stearic acid, oleic acid, and linoleic acid, these means can be seen in Table VI. This indicated that for all time periods the effects of the various batters were not the same. The interaction for palmitic acid can probably be explained by the complete batter increasing from two to eight minutes and then decreasing at the end of 14 minutes, the batter minus egg and non-fat milk solids decreasing from two to eight minutes and increasing from eight to 14 minutes. Batter minus baking powder increased from two through 14 minutes. A similar explanation can be used for the

TABLE VI

THE FATTY ACID CONTENT OF BATTER AS INFLUENCED BY
BOTH BATTER RECIPE AND TIME

Batter	Myristic Acid		
	Time (Min)		
	2	8	14
1	0.37*	0.68	0.57
2	0.90	0.60	0.70
3	0.59	0.39	0.66
4	0.35	0.57	0.70
	Palmitic Acid		
	2	8	14
1	14.91	23.09	16.75
2	20.67	17.47	20.91
3	18.44	13.84	22.77
4	12.80	15.92	21.65
	Palmitoleic Acid		
	2	8	14
1	4.37	7.52	5.05
2	5.65	5.86	9.23
3	7.89	4.97	4.75
4	4.13	6.13	6.15
	Stearic Acid		
	2	8	14
1	5.20	11.53	6.93
2	7.69	6.48	7.85
3	6.89	4.85	6.80
4	4.80	6.09	8.03

Continued

TABLE VI
(Continued)

Batter	Oleic Acid		
	Time (Min)		
	2	8	14
1	38.29	58.34	56.00
2	52.78	51.86	50.80
3	49.38	31.33	55.76
4	33.25	44.30	65.87
Linoleic Acid			
1	78.67	120.98	122.11
2	89.53	101.12	97.54
3	79.92	65.11	134.06
4	77.28	82.75	122.28
Linolenic Acid			
1	21.21	20.33	34.67
2	23.42	28.39	26.83
3	48.35	19.01	35.50
4	21.08	20.74	36.29

Batters

- 1 = Complete
- 2 = Minus egg
- 3 = Minus non-fat milk solids
- 4 = Minus baking powder

*Values given as mg./g.

stearic acid interaction in which the same trends of increase and decrease can be observed. The oleic acid interaction was different because it showed a different trend for the batter minus egg than was encountered in the first two to be discussed. In this interaction batter minus egg decreased slightly from two to 14 minutes instead of the increase at 14 minutes observed in the previous discussion. The linoleic interaction was even more different from the above. The batter minus non-fat milk solids and batter minus baking powder showed a slight if any decrease from two to eight minutes and an increase which was quite apparent from eight to 14 minutes. The complete batter and batter minus egg were the odd ones of this group with an increase from two to eight minutes and then a very small change from eight to 14 minutes.

The oil x batter means in Table VII and the oil x time means in table VIII were found to have no significant interactions.

The cooking oil had the greatest influence on fatty acid content of the batter samples of any variable studied. When the composition of the cooking oils was considered along with the large quantities of oil used it was easy to understand why they play such an important role in the fatty acid composition of the

TABLE VII

THE FATTY ACID CONTENT OF BATTER AS INFLUENCED BY
BOTH OIL AND BATTER RECIPE

Batter	Myristic Acid				
	Oil				
	1	2	3	4	5
1	0.28*	0.34	0.12	1.64	0.33
2	0.21	0.34	0.25	2.03	0.86
3	0.55	0.14	0.15	1.62	0.26
4	0.25	0.23	0.48	1.53	0.21
	Palmitic Acid				
	1	2	3	4	5
1	16.43	17.84	13.84	24.25	18.89
2	15.76	13.02	16.80	38.86	13.98
3	16.10	10.62	17.27	31.27	16.48
4	14.91	13.03	15.03	26.42	14.54
	Palmitoleic Acid				
	1	2	3	4	5
1	2.39	4.77	4.14	13.54	3.41
2	2.86	4.68	3.31	19.32	4.40
3	4.03	2.76	4.05	14.36	4.14
4	4.05	3.85	3.36	13.28	2.80
	Stearic Acid				
	1	2	3	4	5
1	5.20	2.95	3.71	19.92	7.65
2	5.62	2.99	4.51	18.02	5.53
3	5.65	1.86	4.11	12.82	6.43
4	5.47	2.64	4.27	14.15	4.99

Continued

TABLE VII
(Continued)

Oleic Acid					
Oil					
Batter	1	2	3	4	5
1	33.80	46.48	53.16	57.84	63.09
2	35.70	29.49	70.78	63.78	59.31
3	36.25	25.44	56.54	50.87	58.34
4	36.34	32.42	60.72	55.54	54.00
Linoleic Acid					
1	153.02	187.43	64.44	28.34	103.01
2	142.18	99.22	93.73	35.41	109.88
3	142.91	81.36	85.31	38.92	116.67
4	133.18	127.06	75.15	28.54	106.59
Linolenic Acid					
1	75.80	10.40	9.10	2.78	28.91
2	78.46	8.13	9.02	5.05	30.39
3	74.65	11.95	11.10	4.89	68.83
4	71.37	11.82	9.17	6.51	31.30

Batters

- 1 = Complete
- 2 = Minus egg
- 3 = Minus non-fat milk solids
- 4 = Minus baking powder

Oils

- 1 = Cottonseed
- 2 = Corn
- 3 = Peanut
- 4 = Lard
- 5 = Mixed

* Values given as mg./g.

TABLE VIII

THE FATTY ACID CONTENT OF BATTER AS INFLUENCED BY
BY BOTH OIL AND TIME

Myristic Acid

Oil	Time (Min)		
	2	8	14
1	0.29*	0.25	0.42
2	0.16	0.24	0.39
3	0.22	0.27	0.26
4	0.15	0.17	0.19
5	0.56	0.39	0.30

Palmitic Acid

1	15.08	12.92	19.40
2	12.30	13.96	14.63
3	13.61	15.03	18.57
4	29.71	30.73	30.17
5	12.82	15.28	19.81

Palmitoleic Acid

1	3.36	3.60	3.04
2	3.91	4.26	3.87
3	3.28	4.10	3.76
4	14.04	13.99	17.34
5	2.96	4.64	3.45

Stearic Acid

1	5.86	4.28	6.33
2	2.38	2.70	2.75
3	3.55	3.84	5.06
4	14.29	18.96	15.43
5	4.63	6.40	7.42

TABLE VIII
(Continued)

Oleic Acid

Oil	Time (Min)		
	2	8	14
1	35.74	27.39	43.44
2	29.53	36.84	34.01
3	52.90	52.47	75.54
4	53.73	60.12	57.18
5	45.22	55.47	75.37

Linoleic Acid

1	131.90	111.23	185.33
2	97.06	144.44	129.81
3	68.60	75.58	94.79
4	26.03	29.47	42.90
5	83.15	101.80	142.16

Linolenic Acid

1	68.52	56.66	100.03
2	8.10	13.08	10.56
3	9.88	8.13	10.79
4	3.29	4.91	6.23
5	52.79	27.80	38.99

*Values given as mg./g.

batter. The contribution of the individual oils varies to some degree and was not always dependent on the oil with the highest percentage of a fatty acid contributing more of this acid than another oil. Contrary to what was found in the tissue samples, time had a significant effect when oleic and linoleic acids were examined, this may not only include exposure time at elevated temperatures but also cooling time of the sample. The batter recipe was found to be of little importance on the fatty acid composition of the batter but was found to result in possible changes in the cooking medium. The changes, if they were significant, in the cooking medium could result in different fatty acids dominating absorption if the oils were used over an extended period such as in commercial use.

Tissue Samples

Cooking Oil

An analysis was conducted of the various tissue samples to determine the amount of myristic, palmitic, palmitoleic, stearic, oleic, linoleic, and linolenic acids. The analysis of variance of the data for each of the fatty acids is presented in Table IX. Significant differences were noted between oils used to fry the chicken parts when linoleic and linolenic acids were analyzed. Table X shows these differences might be attributable to cottonseed oil which was comparatively high in these two fatty acids. It was interesting to note that although cottonseed oil contributed the largest amount of both linoleic and linolenic acids it does not have the highest content of linoleic acid as seen in Table II. Corn oil had a larger amount of this fatty acid than cottonseed but contributed less to the tissue. Cottonseed did have the largest percentage of linolenic acid in both the tissue and the oil. The other oils fall in line behind cottonseed as they should, with the exception of peanut oil and lard.

Orthogonal comparisons were made to separate the degrees of freedom and determine more accurately where

TABLE IX

ANALYSIS OF VARIANCE OF FACTORS INFLUENCING FATTY
ACID COMPOSITION OF TISSUE AFTER DEEP FAT FRYING

Myristic Acid				
Source	D.F.	S.S.	M.S.	F
Total	119	137.84		
Oil (A)	4	6.30	1.58	1.23
Batter (B)	3	5.55	1.85	1.45
A x B	12	19.71	1.64	1.28
Error a	20	25.57	1.28	
Time (C)	2	7.61	3.80	5.59**
2 vs 8, 14	1	5.40	5.40	7.94**
8 vs 14	1	2.31	2.31	3.40*
B x C	6	9.69	1.61	2.37*
A x C	8	4.17	0.52	0.77*
A x B x C	24	32.11	1.34	1.97*
Error b	40	27.12	0.68	
Palmitic Acid				
Total	119	3,903.51		
Oil (A)	4	221.30	55.33	1.76
Batter (B)	3	187.29	62.43	1.99
A x B	12	503.71	41.98	1.34
Error a	20	626.33	31.32	
Time (C)	2	420.00	209.99	14.61**
2 vs 8, 14	1	181.66	181.66	12.64**
8 vs 14	1	236.67	236.67	16.47**
B x C	6	375.14	62.52	4.35**
A x C	8	52.84	6.61	0.46
A x B x C	24	942.16	39.26	2.73**
Error b	40	574.74	14.37	

Continued

TABLE IX
(Continued)

Palmitoleic Acid				
Source	D.F.	S.S.	M.S.	F
Total	119	1,339.36		
Oil (A)	4	61.66	15.42	1.27
Batter (B)	3	54.17	18.06	1.49
A x B	12	194.50	16.21	1.33
Error a	20	243.08	12.15	
Time (C)	2	12.32	6.16	0.69
B x C	6	21.46	3.58	0.39
A x C	8	83.35	10.42	1.14
A x B x C	24	304.09	12.67	1.39
Error b	40	364.73	9.12	
Stearic Acid				
Total	119	1,238.99		
Oil (A)	4	37.38	9.34	1.47
Batter (B)	3	5.00	1.67	0.26
A x B	12	166.17	13.85	2.18
Error a	20	127.02	6.35	
Time (C)	2	33.31	16.66	1.35
B x C	6	43.14	7.19	0.58
A x C	8	58.00	7.25	0.59
A x B x C	24	276.55	11.52	0.94
Error b	40	492.43	12.31	

Continued

TABLE IX

(Continued)

Oleic Acid				
Source	D.F.	S.S.	M.S.	F
Total	119	7,163.14		
Oil (A)	4	141.67	35.42	0.51
Batter (B)	3	109.73	36.58	0.52
A x B	12	808.00	67.33	0.96
Error a	20	1,401.51	70.08	
Time (C)	2	590.00	295.01	4.93*
2 vs 8,14	1	208.32	208.32	3.48
8 vs 14	1	381.94	381.94	6.39*
B x C	6	216.99	36.17	0.61
A x C	8	269.07	33.63	0.56
A x B x C	24	1,234.68	51.45	0.86
Error b	40	2,391.49	59.79	
Linoleic Acid				
Total	119	7,747.97		
Oil (A)	4	953.75	238.44	6.17**
4 vs 1,2,3,5	1	22.81	22.81	0.59
1,5 vs 2,3	1	107.87	107.87	2.79
2 vs 3	1	110.90	110.90	2.87
Batter (B)	3	949.15	316.39	8.18**
1 vs 2,3,4	1	2.21	2.21	0.06**
2 vs 3,4	1	924.80	924.80	23.91**
3 vs 4	1	21.20	21.20	0.56
A x B	12	581.74	48.48	1.25
Error a	20	773.54	38.68	
Time (C)	2	321.64	160.82	4.02*
2 vs 8,14	1	124.42	124.42	3.11*
8 vs 14	1	197.19	197.19	4.93*
B x C	6	247.19	41.20	1.03*
A x C	8	710.49	88.81	2.22*
A x B x C	24	1,611.85	67.16	1.68
Error b	40	1,598.63	39.97	

Continued

TABLE IX

(Continued)

Linolenic Acid

Source	D.F.	S.S.	M.S.	F
Total	119	466.13		
Oil (A)	4	117.03	29.26	11.11**
4 vs 1,2,3,5	1	4.80	4.80	1.83
1,5 vs 2,3	1	67.74	67.74	25.76**
2 vs 3	1	4.04	4.04	1.53*
Batter (B)	3	34.55	11.52	4.37*
1 vs 2,3,4	1	3.84	3.84	1.46
2 vs 3,4	1	25.76	25.76	9.80**
3 vs 4	1	4.87	4.87	1.85
A x B	12	31.00	2.58	0.98
Error a	20	52.67	2.63	
Time (C)	2	17.94	8.97	3.27
B x C	6	28.59	4.77	1.74
A x C	8	14.27	1.78	0.65
A x B x C	24	60.23	2.51	0.91
Error b	40	109.86	2.75	

** Significant at the 0.01 level of probability

* Significant at the 0.05 level of probability

Orthogonal Comparisons

Oils

- 1 = Cottonseed
- 2 = Corn
- 3 = Peanut
- 4 = Lard
- 5 = Mixed

Times

- 2 = Two minutes
- 8 = Eight minutes
- 14 = Fourteen minutes

Batters

- 1 = Complete
- 2 = Minus egg
- 3 = Minus non-fat milk solids
- 4 = Minus baking powder

TABLE X

THE FATTY ACID CONTENT OF TISSUE SAMPLES AFTER
COOKING IN VARIOUS OILS

Oils	Fatty Acid (mg./g.)						
	C ₁₄	C ₁₆	C _{16:1}	C ₁₈	C _{18:1}	C _{18:2}	C _{18:3}
1	1.10	8.27	4.14	2.81	12.69	17.54	4.11
2	1.06	7.91	2.67	2.38	12.26	13.08	1.80
3	1.53	10.10	3.75	3.11	12.99	10.05	1.22
4	1.14	10.57	4.70	3.95	12.79	11.54	1.85
5	0.82	6.98	3.14	2.53	10.03	9.84	2.27

Cooking Oils

- 1 = Cottonseed
- 2 = Corn
- 3 = Peanut
- 4 = Lard
- 5 = Mixed

the differences were to be found. The comparisons are shown in Table IX. The comparison between the animal (lard) and plant sources (oils) and the corn oil, peanut oil comparison were found to be nonsignificantly different. The cottonseed and mixed oils versus corn and peanut oils comparison was highly significant in the case of linolenic acid and not significant in linoleic acid. It was readily apparent that the comparisons made for linoleic acid did not reflect where the differences were to be found. Linolenic acid gave more of an indication but the small amount of the variance accounted for by this comparison leaves some doubt as to the importance of this difference.

A most interesting phenomenon seems to be presented by the linoleic acid means which appear to be reversed. A closer examination of Table II will show that linoleic and linolenic acids were more evenly distributed in cottonseed oil than any of the other oils. To the contrary however corn which had the second largest total of linoleic acid (Table X) had a more uneven distribution than all the others. The others seem to follow the example of cottonseed, the largest content of the fatty acids being found in those which were more evenly

balanced or equal in content. Perhaps linolenic acid had an influence on linoleic acid which enhances movement of fats containing these fatty acids from the cooking medium through the batter and into the tissue sample. It was also interesting to note that both of these fatty acids were unsaturated and 18 carbon chained, the unsaturation occurred at the 9 and 12 position for linoleic acid and 9,12, and 15 positions for linolenic acid. The 12 position could have importance when it is considered that oleic acid is an 18 carbon fatty acid unsaturated in the 9 position and was not significant.

Batter Recipe

Batter recipe effects were found only in the cases of linoleic and linolenic acid levels in the tissue. These means are shown in Table XI. Greater linoleic and linolenic acid levels were reflected when egg was omitted from the batter. The removal of the egg was compensated for by addition of water to maintain the uniform consistency desired. The water could have been removed from the batter as steam and the oil may have moved in to replace the water and in this way come into contact with the tissue sample. The confusing part of this was that in the analysis of the batter

TABLE XI
THE FATTY ACID CONTENT OF TISSUE AFTER USING DIFFERENT
BATTER RECIPES

Batter	Fatty Acid (mg./g.)						
	C ₁₄	C ₁₆	C _{16:1}	C ₁₈	C _{18:1}	C _{18:2}	C _{18:3}
1	0.96	7.33	3.34	3.04	11.84	12.65	1.94
2	0.90	10.38	3.82	2.87	13.76	16.87	3.11
3	1.44	9.57	2.88	2.68	11.24	9.46	1.69
4	1.22	7.79	4.69	3.23	11.76	10.67	2.26

Batters

- 1 = Complete
- 2 = Minus egg
- 3 = Minus non-fat milk solids
- 4 = Minus baking powder

samples no significant differences could be attributed to the batter recipe. The difference between the batter minus baking powder and the complete batter could be of little significance in the case of linolenic acid due to the nearness of the means. The difference of two mg./g. of tissue in the linoleic acid means was too large to be ignored. The lack of baking powder apparently resulted in a decrease in the amount of gas formation which caused a thinner but more solid barrier to the oil which hardened to quite an extent upon heating and therefore, reduced the amount of penetration of this fatty acid. The removal of the non-fat milk solids appears to have increased the penetration of oil the least of all.

Orthogonal comparisons of the batter samples were conducted to try and separate the degrees of freedom necessary to aid the analysis. At the onset of the experiment it was decided to compare the complete batter to the others (1 vs 2,3,4), the batter minus egg to the batters minus non-fat milk solids and baking powder (2 vs 3,4) and finally the batter minus the non-fat milk solids to the one minus the baking powder (3 vs 4). The only comparison which proved to be significant for both the fatty acids, linoleic and

linolenic, was the second (2 vs 3,4). These were found to be highly significantly different and were the only differences found for either fatty acid. As the analysis of the means indicated the batter in which the egg was removed resulted in a significant increase of these two fatty acids in the tissue sample.

The same two fatty acids which had a significant difference attributable to cooking oil also demonstrated a significant batter effect. Batter and oil were apparently complementary because without the fatty acids being present in the oil there could be no penetration and likewise if the batter reduces or stops penetration, very little difference would be noticed. The enhancement of penetration could have a simple explanation such as the removal of egg removes a large amount of lipid and thereby facilitating movement into the batter and through to the tissue.

Time

The significant differences attributable to time are presented in Table IX. In this table time of cooking had an influence which was significant when

myristic, palmitic, oleic, and linoleic acids were considered. Linolenic acid approached significance. The means of the fatty acid content of tissue samples are shown in Table XII. An increase as time increased was found to be the case for all of the fatty acids when the mean values were observed. This indicated that movement into and through the batter barrier was not simply an immediate uncomplicated movement but one into which several factors were brought to bear often over a period of time. The cooling time was increased as the temperature was maintained for longer periods of time and could have an influence on the penetration of the oil.

Orthogonal comparisons were run in an attempt to separate any differences which would occur here into significant and not significant changes. Table IX shows that only the fatty acids which had significant differences due to time were chosen for the comparisons. A highly significant difference was found when the two minute period was compared to the eight and 14 minute time periods in the case of myristic acid and palmitic acid. The comparison of the eight and 14 minute periods revealed a highly significant difference for palmitic acid and a significant difference for oleic

TABLE XII
THE FATTY ACID CONTENT OF TISSUE SAMPLES AFTER COOKING
FOR VARIOUS TIME PERIODS

Time (Min)	Fatty Acid (mg./g.)						
	C ₁₄	C ₁₆	C _{16:1}	C ₁₈	C _{18:1}	C _{18:2}	C _{18:3}
2	0.83	7.03	3.30	3.17	10.29	10.97	1.93
8	1.11	7.91	3.66	2.23	10.90	11.56	2.03
14	1.45	11.36	4.08	3.46	15.27	14.70	2.79

acid and linoleic acid. These comparisons indicated that a significant increase in the fatty acid content occurred after two, eight, and 14 minutes when palmitic acid was measured. Myristic acid was discovered to increase after being cooked for eight or 14 minutes with no differences being noted between the eight and 14 minute periods. Increased fatty acid content of tissue was observed when palmitic, oleic, and linoleic acids were cooked for 14 minutes when compared to the content of the tissue after eight minutes.

The heating of the batter with its consequent removal of water and formation of a hard coating around the tissue sample could result in, over a time period, an effect on the penetration into the tissue sample even though it is not the entire answer. The reason for all the fatty acids considered being significantly different and not stearic and palmitoleic acids was unexplainable with this data. Perhaps the answer lies in physical characteristics, palmitoleic is a 16 carbon fatty acid with a double bond at the 9 position and stearic is a saturated 18 carbon fatty acid. The movement through the batter to the tissue of the oil over a period of time was enhanced when saturated fatty acids of 16 carbons or less and

unsaturated fatty acids of 18 carbons compose the triglyceride. The obvious answer of increased migration because of more time in which to accomplish the task does not explain the reason only these were significant. The fact that palmitic, oleic, linoleic, and linolenic acids were present in large quantities in the oil does not explain why these show an increase in the tissue with time. If the total amount is considered to be the criteria of penetration then the one present in the oils in the largest quantity (Table. II) would have the greatest increase over the time periods. Linoleic acid would have the greatest increase followed by oleic, palmitic, linolenic, stearic, palmitoleic, and myristic acids in decreasing order of magnitude. It was readily discernable that the order of amount of penetration increase was oleic acid followed by palmitic, linoleic, linolenic (which only approaches significance), and myristic acids. The others, palmitoleic and stearic acids, were not significant for time. Myristic acid was very low in the oil samples, less than 0.1 mg./g. of oil except in the case of lard, yet an increase was noted from two to eight and eight to 14 minutes of 0.272 and 0.343 mg./g. of tissue respectively. This could suggest a type of concentrating mechanism.

On the basis of the evidence a solution based on amount present in the cooking oil must be rejected.

Interactions

Table IX indicates that significant batter x time interactions were found for both myristic acid and palmitic acid. The means for these fatty acids can be found in Table XIII. Myristic acid had a significant interaction because all batters did not have the same effect for all time periods. The complete batter across the three time periods showed an increase for two to eight minutes and a decrease from eight to 14 minutes. The other batters showed an increase from two through 14 minutes. The palmitic acid interaction, similar to myristic acid, showed an increase from two to eight minutes for the complete batter followed by a decrease from eight to 14 minutes. The batters minus egg and non-fat milk solids had an increase from two through 14 minutes. The batter minus baking powder showed a decrease from two to eight minutes then a increase from eight to 14 minutes. These differences apparently caused the interaction to be significantly different.

The examination of the oil x time interaction in

TABLE XIII
THE FATTY ACID CONTENT OF TISSUE AS INFLUENCED BY
BOTH BATTER RECIPE AND TIME

Batter	Myristic Acid Time (Min)		
	2	8	14
1	1.06 *	1.22	0.61
2	0.42	0.81	1.46
3	1.03	1.20	2.08
4	0.82	1.20	1.65
Palmitic Acid			
1	7.67	8.02	6.31
2	6.34	9.47	15.33
3	7.27	9.26	12.17
4	6.83	4.91	11.65
Palmitoleic Acid			
1	3.21	3.83	2.98
2	2.93	4.01	4.51
3	2.22	2.67	3.74
4	4.83	4.15	5.10
Stearic Acid			
1	2.55	2.24	4.34
2	2.36	2.69	3.55
3	3.12	2.01	2.91
4	4.65	1.98	3.05

Continued

TABLE XIII

(Continued)

Batter	Oleic Acid Time (Min)		
	2	8	14
1	11.69	11.48	12.36
2	10.81	13.37	17.09
3	10.18	9.04	14.49
4	8.47	9.70	17.12
Linoleic Acid			
1	11.84	10.02	16.09
2	13.19	15.94	21.47
3	8.54	9.91	9.94
4	10.31	10.38	11.30
Linolenic Acid			
1	1.70	1.82	2.30
2	2.07	2.45	4.82
3	1.67	1.61	1.78
4	2.27	2.23	2.28

* Values given as mg./g.

Batters

1 = Complete

2 = Minus egg

3 = Minus non-fat milk solids

4 = Minus baking powder

Table IX shows a significant interaction when levels of linoleic acid are examined. It is possible to compare the means in Table XIV in an attempt to find where the interactions occurred by looking for trends which are in different directions. Cottonseed and corn oils when considered across time seem to be the ones which acted differently. As mentioned previously, the trend seems to be to have an increase in concentration as time increases. This was not the case for these two oils where a decrease from two to eight minutes followed by an increase to 14 minutes was noted for cottonseed oil. Corn oil showed a decrease across all three times instead of the expected increase. The other three oils follow the trend of increasing as time increased as was indicated by the data.

Table IX shows the oil x batter interaction which demonstrated no significance. The means can be found in Table XV and are included only for comparison purposes.

The analysis of the meat samples were different from the batter samples in regard to what had an effect on the concentration changes of the various fatty acids. The oil which the chicken part was fried had frequently very little effect on the fatty acid profile of the meat with the exception of linoleic

TABLE XIV
THE FATTY ACID CONTENT OF TISSUE AS INFLUENCED BY
BOTH OIL AND TIME

Myristic Acid

Oil	Time (Min)		
	2	8	14
1	0.66*	1.49	1.14
2	0.55	1.10	1.53
3	1.43	1.19	1.97
4	0.93	1.02	1.49
5	0.61	0.73	1.12

Palmitic Acid

1	6.53	6.34	11.95
2	6.66	7.38	9.71
3	8.65	8.73	12.93
4	7.93	10.15	13.64
5	5.36	6.97	8.60

Palmitoleic Acid

1	5.18	4.17	3.08
2	2.71	2.96	2.36
3	2.79	2.76	5.71
4	4.08	5.01	5.03
5	1.75	3.42	4.25

Stearic Acid

1	2.47	2.58	3.38
2	2.58	2.15	2.39
3	2.15	2.53	4.65
4	5.71	2.35	3.80
5	2.95	1.53	3.09

TABLE XIV

(Continued)

Oleic Acid

Time (Min)

Oil	2	8	14
1	12.61	9.93	15.53
2	12.93	10.77	13.07
3	9.39	13.88	15.69
4	9.23	11.36	17.77
5	7.26	8.55	14.28

Linoleic Acid

1	15.83	13.76	23.03
2	15.99	13.87	9.39
3	7.08	10.63	12.45
4	9.47	10.37	14.78
5	6.47	9.19	13.85

Linolenic Acid

1	3.44	3.47	5.42
2	1.87	1.87	1.65
3	0.93	1.24	1.49
4	1.56	1.56	2.42
5	1.82	2.01	2.98

*Values given as mg./g.

Oils

- 1 = Cottonseed
- 2 = Corn
- 3 = Peanut
- 4 = Lard
- 5 = Mixed

TABLE XV

THE FATTY ACID CONTENT OF TISSUE AS INFLUENCED BY
BOTH OIL AND BATTER RECIPE

Batter	Myristic Acid				
	Oil				
	1	2	3	4	5
1	1.01*	0.56	1.91	1.00	0.32
2	0.92	0.63	1.78	0.53	0.63
3	0.73	1.41	1.74	1.61	1.69
4	1.72	1.63	0.68	1.43	0.63
	Palmitic Acid				
	1	2	3	4	5
1	6.23	6.30	10.99	8.39	4.75
2	9.39	8.01	14.81	9.31	10.37
3	9.20	6.63	10.42	13.31	8.28
4	8.27	10.72	4.19	11.28	4.50
	Palmitoleic Acid				
	1	2	3	4	5
1	1.92	2.80	5.45	3.14	3.38
2	2.42	2.95	3.63	6.43	3.67
3	5.89	1.80	2.58	2.06	2.06
4	6.33	3.15	3.36	7.18	3.45
	Stearic Acid				
	1	2	3	4	5
1	2.34	2.84	4.77	3.38	1.89
2	2.79	2.77	3.73	2.09	2.96
3	3.10	1.56	2.34	2.76	3.64
4	3.01	2.35	1.59	7.59	1.61

Continued

TABLE XV
(Continued)

Batter	Oleic Acid Oil				
	1	2	3	4	5
1	9.31	14.30	13.50	13.70	8.41
2	10.52	14.16	15.98	12.78	15.35
3	12.46	7.30	13.29	13.63	9.52
4	18.48	13.28	9.17	11.05	6.83
Linoleic Acid					
1	17.86	17.77	7.86	11.08	8.68
2	18.69	17.94	15.55	14.18	17.98
3	16.39	7.96	9.86	8.08	5.03
4	17.23	8.68	6.94	12.82	7.66
Linolenic Acid					
1	2.57	2.07	0.76	1.88	2.42
2	4.93	2.70	1.68	2.38	3.86
3	4.02	0.96	1.25	1.14	1.07
4	4.91	1.47	1.19	1.99	1.72

* Values given as mg./g.

Oils

- 1 = Cottonseed
- 2 = Corn
- 3 = Peanut
- 4 = Lard
- 5 = Mixed

Batters

- 1 = Complete
- 2 = Minus egg
- 3 = Minus non-fat milk solids
- 4 = Minus baking powder

and linolenic acids where highly significant differences were detected. This was different from that found for the batter samples in which oil was the main factor influencing these changes. Changing the ingredients of the batter only influenced the linoleic and linolenic acid concentration of the meat. Removal of egg gave the greatest increase followed by the complete batter and the batter minus the baking powder. The order of the last two depending on which fatty acid, linoleic or linolenic, was being considered. The one factor affecting more fatty acids in the meat than any other was time. The ones not showing an increase in concentration as time increased were palmitoleic, stearic, and linolenic acids, with the latter approaching significance. A simple explanation of why these particular fatty acids did not increase with time was not found.

SUMMARY

The possible changed nutritional value of fats and oils heated to high temperature has been a concern for several years. With deep fat fried foods assuming a place of importance in the diets of many individuals, the changes which occur in the product as a result of frying in various fats and oils are very important factors which deserve consideration.

This experiment was conducted to determine the effects of various cooking oils, batter recipes, and times of cooking on the fatty acid composition of the batter and meat product during frying. In addition, it was desirable to determine whether the composition of the oil was changed.

The oils penetrated into and through the batter into the tissue sample. The fatty acids in the batter and tissue were found to be influenced by the cooking oil used in both cases. When the composition of the cooking oils was considered along with the large quantities of a oil used it was easy to understand why they play such an important role in the fatty acid composition of the batter. The contribution of the individual oil varies to some degree and was not always

dependent on the oil with the highest percentage of a fatty acid contributing more of this acid than another oil. The cooking oil had very little effect on the fatty acid profile of the meat, with the exception of linoleic and linolenic acids where significant differences were detected. This was different from the batter samples where the oil was found to be the main factor influencing these changes. The factor having the greatest influence on the tissue samples was time of cooking. The only fatty acids not showing an increase in concentration as time increased were palmitoleic, stearic, and linolenic acids, with the latter approaching significance. A significant time effect was found in the batter samples when oleic and linoleic acids are considered. Changing the ingredients of the batter only influenced two fatty acids, linoleic and linolenic, to any extent and these were both found in the tissue samples. Batter recipe was found to be of importance when possible changes in the cooking medium were found to result when the recipe was changed.

CONCLUSIONS

The results obtained from this study indicate the following conclusions appear warranted.

1. Cooking oils are absorbed and/or adsorbed into and through the batter and into the tissue during deep fat frying as evidenced by a change in fatty acid composition.

2. The cooking oils determined the fatty acid profile in the batter samples.

3. The tissue content of both linoleic and linolenic acids were found to be affected by the cooking oil.

4. Lard was significantly different from the other oils in the amounts of the various fatty acids found in the batter. Cottonseed and mixed oils contributed more saturated fatty acids than did corn and peanut oils. Corn oil contributed less stearic and oleic acids than peanut but more linoleic and linolenic acids. Corn oil contributed less saturates than any of the other five oils followed by peanut and cottonseed oils.

5. Oleic and linoleic acids increased in the batter as cooking time increased. The greatest

increase was found between the eight and 14 minute periods.

6. The increase of cooking time resulted in an increased content of myristic, palmitic, oleic, and linoleic acids in the tissue with the exception of myristic acid, the eight to 14 minute time period showed the greatest increase.

7. The batter recipe was found to affect only linoleic and linolenic acid composition of the tissue and was thought to have an effect upon the cooking oil depending upon what was excluded.

8. The removal of egg from the batter resulted in an increase in the tissue content of linoleic and linolenic acids.

REFERENCES

- Bailey, A. E., 1951. Industrial oil and fat products.
2nd edition. Interscience Publishers, New York.
- Bennion, M. and F. Hanning, 1956a. Decomposition of
lard in the frying of French-fried potatoes and
of fritter type batters. J. Home Econ. 48:184-
188.
- Bennion, M. and F. Hanning, 1956b. Effect of differ-
ent fats and oils and their modifications on
changes during frying. Food Tech. 10:229-232.
- Brown, J. B., 1959. Changes in nutritive value of
food fats during processing and cooking.
Nutrition Revs. 17:321-325.
- Carlin, G. T., R. P. Hopper and B. N. Rockwood, 1954.
Some factors affecting the decomposition of
frying fats. Food Tech. 8:161-165.
- Carlin, G. T. and E. Lannerud, 1941. Rancidity
problems in baked and fried foods. Oil and
Soap. 18:60-62.
- Chang, I. C. L. and B. M. Watts, 1952. The fatty
acid content of meat and poultry before and
after cooking. J. Amer. Oil Chemists Soc. 29:
334-338.
- Chung, R. A., J. A. McKay and C. L. Ramey, 1966.
Fatty acid changes in beef, pork, and fish
after deep fat frying in different oils. Food
Technol. 20:123-125.
- Fisher, D. E., 1949. Fat absorption and symmetry in
cake doughnuts. Bakers Weekly, 144:88.
- Fleischman, A. I., A. Florin, J. Fitzgerald, A. B.
Caldwell, and G. Eastwood, 1963. Studies on
cooking fats and oils. J. Amer. Dietetic Assn.
42:394-398.

- Frazer, C. B. E., 1964. Chemical and nutritional aspects of oxidized and heated fats. Chem. and Ind. 1531-1543.
- Goodman, A. H. and Z. Block, 1952. Problems encountered in the commercial utilization of frying fats. J. Oil Chem. Soc. 29:616-619.
- Keane, K. W., G. A. Jacobson and C. H. Krieger, 1959. Biological and chemical studies on commercial frying oils. J. Nutr. 68:57-74.
- Kilgore, L. T. and W. D. Luker, 1964. Fatty acid components of fried foods and fats used for frying. J. Amer. Oil Chem. Soc. 41:496-500.
- King, F. B., R. Loughlin, R. W. Riemenshneider and N. R. Ellis, 1936. The relative value of various lards and other fats for the deep fat frying of potato chips. J. Agr. Res. 53:369-381.
- Kritchevsky, D., J. F. Berry and D. A. Turner, 1961. Cholesterol vehicle in experimental atherosclerosis. III. Effects of absence or presence of fatty vehicle. J. Amer. Oil Chem. Soc. 38:74-76.
- Lantz, C. W. and G. T. Carlin, 1938. Stability of fats used for deep fat frying. Oil and Soap. 15:38-41.
- Lowe, B., P. M. Nelson and J. H. Buchanan, 1940. The physical and chemical characteristics of lard and other fats in relation to their culinary value. III. For frying purposes. Iowa Agricultural Expt. Sta., Ames Iowa, Research Bulletin. 279: 876-926.
- Lowe, B., S. Prodhon and J. Kastelic, 1958. The free fatty acid content and smoke point of some fats. J. Home Econ. 50:778.
- McKee, M. C., 1918. Fat absorption in frying doughnuts. J. Home Econ. 10:18-20.
- Melnick, D., 1957. Absence of thermal polymers in potato chip frying oils. J. Amer. Oil Chem. Soc. 34:351-356.

- Melnick, D., 1957. Nutritional quality of frying fats in commercial use. J. Amer. Oil Chem. Soc. 34: 578-582.
- Melnick, D., F. H. Luckmann and C. M. Gooding, 1958. Composition and control of potato chip frying oils in continuing commercial use. J. Amer. Oil Chem. Soc. 35:271-276.
- Perkins, E. G., 1960. Nutritional and chemical changes occurring in heated fats. A review. Food Technol. 14:508-514.
- Perkins, E. G. and F. A. Kummerow, 1959. The isolation and characterization of the polymers formed during the thermal oxidation of corn oil. J. Amer. Oil Chem. Soc. 36:371-374.
- Perkins, E. G. and L. A. Van Akkeren, 1965. Heated fats. IV. Chemical changes in fats subjected to deep fat frying process: Cottonseed oil. J. Amer. Oil Chem. Soc. 42:782-785.
- Poling, C. E., W. D. Warner, P. E. Mone and E. E. Rice, 1962. The influence of temperature, heating time, and aeration upon the nutritive value of fats. J. Amer. Oil Chem. Soc. 39:315-320.
- Rice, E. E., P. E. Mone and C. E. Poling, 1957a. Effect of commercial frying operations on nutritive value of fats. Fed. Proc. 16:398.
- Robinson, H. E., H. C. Block and H. S. Mitchell, 1940. Studies relating to the foaming tendencies in edible oils and fats. Oil and Soap. 17:208-210.
- Rust, M. E. and D. L. Harrison, 1960. The effect of method of care on the frying life of fat. Food Technol. 14:605-609.
- Smith, A. A. and G. Vail, 1961. Yield and composition of broiler fryers fried by three methods. J. Amer. Dietetic Assn. 43:541-544.
- Steel, R. G. D. and J. H. Torrie, 1960. Principles and Procedures of Statistics. McGraw-Hill Book Co., Inc., New York.

- Teekell, R. A., 1968. Personal Communication.
Poultry Science Department, Louisiana State
University.
- Thiessen, E. J., 1939. Various fats used in deep fat
frying of dough mixtures at high altitudes. Food
Res. 4:135-144.
- Thompson, J. A., M. M. Paulose, B. R. Reddy, R. G.
Krishnamurthy and S. S. Chang, 1967. A limited
survey of fats and oils commercially used for
deep fat frying. Food Technol. 21:87-89.
- Wishner, L. A. and M. Keeney, 1965. Comparative study
of monocarbonyl compounds formed during deep
frying in different fats. J. Amer. Oil Chem.
Soc. 42:776-778.
- Woodruff, S. and K. Blunt, 1919. Changes in fats
absorbed by fried foods. J. Home Econ. 11:440-
452.
- Weir, E. C., A. Slover, C. Pohl and P. D. Wilson,
1962. Effect of cooking procedures on the
composition and organoleptic properties. Food
Technol. 5:133.

AUTOBIOGRAPHY

I was born December 6, 1939, in Monroe, Louisiana, the son of James L. and Alodi B. Heath. I attended elementary and high school in Calhoun, Louisiana, and was graduated in May, 1958.

I entered Louisiana State University in September, 1958, and graduated with a Bachelor of Science degree and was commissioned an officer in the United States Army in January, 1963.

After completion of my military service, I was admitted to the Graduate School of Louisiana State University in June, 1965, and received a Masters of Science degree in the Poultry Science Department. Since that time I have pursued a curriculum leading toward a Doctor of Philosophy degree in Poultry Science with a major in Market Products and a minor in Biochemistry.

I am married to the former Mary Alice Noble of Baton Rouge, Louisiana.

EXAMINATION AND THESIS REPORT

Candidate: James Lee Heath III

Major Field: Poultry Science

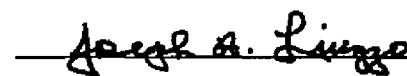
Title of Thesis: Fatty Acid Composition of Batter Coated Chicken Parts

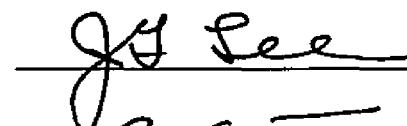
Approved:


Major Professor and Chairman


Dean of the Graduate School

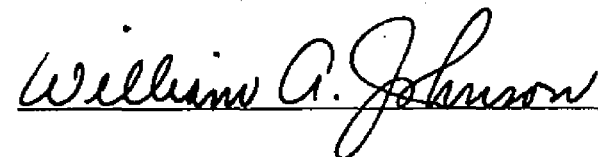
EXAMINING COMMITTEE:











Date of Examination: _____

February 6, 1970